U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 45.

# SOME INSECTS INJURIOUS TO STORED GRAIN.

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(Revised edition.)

[February, 1897.]

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1897.

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# SOME INSECTS INJURIOUS TO STORED GRAIN.

Stored grain is subject to injury by insects of several kinds, popularly termed "weevil." Upward of two score of species occur commonly in granaries, three living throughout their adolescent stages within the kernel of the grain. These three are the granary weevil, rice weevil, and Angoumois grain moth, the most injurious forms, both at home and abroad. The remaining species live on grain in the kernel, also when manufactured into flour and meal, and feed as well on various other edible products; hence, though of comparatively little importance as the authors of primary injury to the seed, they are very frequently the cause of serious damage to manufactured products and to grain that has suffered first from the attacks of the weevils or grain moth and has been kept for a length of time in store.

Nearly all of the grain-feeding species known in the United States have been introduced and are now cosmopolitan, having been distributed by commerce to all quarters of the earth, no insects being more easily carried from one land to another, since they breed continuously for years in the same grain and are unknowingly transported when in an immature state in the kernels. Most of our indoor insects are indigenous to the Tropics and do not thrive in the cold climate of our extreme northern States, but in the South they have become acclimated and there do their greatest damage.

## NATURE AND EXTENT OF DAMAGE.

Aside from the loss in weight occasioned by the ravages of insects, grain infested by them is unfit for human consumption, and has been known to cause serious illness. Nor is such grain desirable for food for live stock or for seed, its use in the latter capacity being apt to be followed by a diminution in the yield of a crop.

Of the insect injury to stored grain it has been estimated of Texas alone that there is an annual loss of over a million dollars, and that nearly 50 per cent of the corn of that State is annually destroyed by weevils and rats. The loss from granary insects to the corn crop in Alabama in 1893 was estimated at $1,671,382, or about 10 per cent.

There are seven other States subject to the same atmospheric and other influences as Alabama and producing in the aggregate a somewhat larger average yield of corn. Estimating the annual loss in the same proportions, we would have for these eight Southern States, viz: South

Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Texas, and Arkansas, a total of nearly $20,000,000. This is for corn alone, and does not take into consideration wheat and other grains or mill products.

In regard to the susceptibility of different grains to "weevil" attack, it may be said that unhusked rice, oats, and buckwheat are practically exempt, but the hull of barley offers less protection to the seed. Husked or hulled grains are naturally more exposed to infestation, and the softer varieties suffer far more injury than do the harder, flinty sorts.

In times when grain was kept long in store, and long voyages were necessary in its transportation, losses through the depredations of insects were much heavier than at present, these pests being exceedingly prolific and increasing enormously under such conditions. Heat and dampness, the latter inducing a condition of the grain termed "heating," also favor the undue increase of insect life, and the insects, when present in large numbers, cause, in some unexplained manner, a very perceptible rise in temperature to the infested mass. It is unnecessary to add that dampness and "heating" alone do not of themselves engender "weevil," every individual insect owing its existence to an egg deposited in the grain by the parent insect.

## THE GRAIN WEEVILS.

All the various species of insects that attack stored grain are indiscriminately called weevils, or simply "weevil," but the only true grain weevils are the granary weevil and rice weevil.

These two insects resemble each other in structure as well as in habit. They are small, flattened, brown snout-beetles of the family Calandridæ. Neither is more than a sixth of an inch in length, but their rate of development is so rapid that they do an almost incalculable amount of injury in a short period of time. Their heads are prolonged into a long snout or proboscis, at the end of which are the mandibles; their antennæ are elbowed and are attached to the proboscis.

### THE GRANARY WEEVIL (*Calandra granaria* Linn.).

The granary weevil has been known as an enemy to stored grain since the earliest times. Having become domesticated ages ago, it has long since lost the use of its wings and is strictly an indoor species.

The mature weevil measures from an eighth to a sixth of an inch, is uniform shining chestnut brown in color, and has the thorax sparsely and longitudinally punctured, as indicated, much enlarged, at fig. 1, *a*.

The larva is legless, considerably shorter than the adult, white in color, very robust, fleshy, and of the form shown in the illustration (*b*). The pupa, illustrated at *c*, is also white, clear, and transparent, exhibiting the general characters of the future beetle.

The female punctures the grain with her snout and then inserts an egg, from which is hatched a larva that devours the mealy interior and

undergoes its transformations within the hull. In wheat and other small cereals a single larva inhabits a grain, but a kernel of maize furnishes food for several individuals.

The time required for the completion of the life cycle varies with the season and climate, and the number of generations annually produced is consequently dependent upon temperature. The midsummer period from egg to adult is about six weeks, and there may be, under favoring conditions, four or five broods in this latitude and six or even more in the South.

This species is injurious in wheat, maize, barley, and other grains and attacks also the chick-pea (*Cicer arietinum*), a food product of the Tropics. Unlike the moths which attack grain, the adult weevils feed also upon the kernels, gnawing into them for food and for shelter, and, being quite long-lived, probably do even more damage than their larvæ. This species is very prolific, egg-laying continuing over an extended period. It has been estimated that one pair will, in the course of a year, produce 6,000 descendants, and it will be seen that the progeny of a single pair are capable in a short time of causing considerable damage.

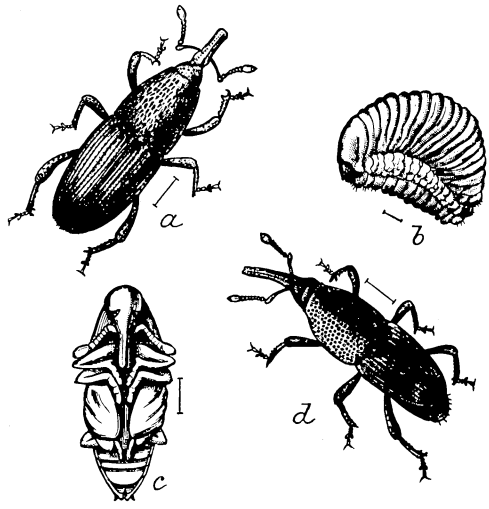


FIG. 1.—*Calandra granaria: a*, beetle; *b*, larva; *c*, pupa; *d*, *C. oryza*, beetle—all enlarged (author's illustration).

THE RICE WEEVIL (*Calandra oryza* Linn.).

A very similar insect to the preceding is the rice weevil, which derives both its popular and Latin name from rice (oryza), in which it was originally discovered. It is conceded to have originated in India, whence it has been diffused by commerce until it is now established in most of the grain-growing countries of the world. It is a serious pest in the Southern States, where it is commonly, though erroneously, called "black weevil," but farther north is of less importance. It occurs, however, in every State and Territory in the Union, and occasionally invades Canada and Alaska.

This species resembles the granary weevil in size and general appearance, but differs in being dull brown in color, in having the thorax densely pitted with round punctures, and the elytra, or wing cases, ornamented with four more or less distinct red spots, arranged as in the illustration (fig. 1, *d*). Unlike the preceding species it has well-developed and serviceable wings. The larvæ and pupæ are also similar

to those of the granary weevil, and in habits and life history these two species do not materially differ, except in that the rice weevil may often be found in the field remote from the granary, and in the extreme South and in the Tropics lays it eggs in standing grain.

The rice weevil feeds upon the grain of rice, wheat, particularly the soft varieties, maize, barley, rye, hulled oats, buckwheat, chick-peas, and the cultivated varieties of sorghum known as Kafir, or Jerusalem corn, etc., and the adult beetles, when abundant in storehouses and groceries, invade boxes of crackers, cakes, and other breadstuffs, barrels of flour and bags of meal.

## THE GRAIN MOTHS.

### THE ANGOUMOIS GRAIN MOTH (*Sitotroga cerealella* Ol.).

This moth received its name from the province of Angoumois, France, where it is known to have been injurious since the year 1736. In this country, where it is familiarly but incorrectly called "fly weevil," it is said to have been recognized as early as 1728. From the seat of its supposed introduction, in North Carolina and Virginia, this moth has spread to neighboring States in the South, where it does incalculable damage, and to the southern portions of the Northern States, where it is less injurious. Although not so widely distributed as the true grain weevils, it is rapidly increasing its range, and as it attacks grain in the field, even as far north as central Pennsylvania, as well as in the bin, is even a more serious pest in the localities in which it has become established than the weevils. It infests all the cereals, as well as buckwheat and the chick-pea, product of the Tropics. It has been estimated that in six months grain infested by this moth loses 40 per cent in weight and 75 per cent of farinaceous matter.

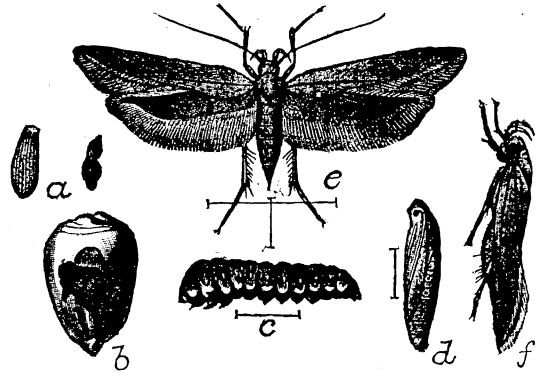


FIG. 2.—*Sitotroga cerealella*: *a*, eggs; *b*, larva at work; *c*, larva, side view; *d*, pupa; *e*, moth; *f*, same, side view (original).

The adult insect resembles somewhat a clothes moth, for which indeed it is often mistaken. It is light grayish brown in color, more or less lined and spotted with black, and measures across the expanded fore-wings about half an inch (see fig. 2). The hind-wings are bordered with a long, delicate fringe.

The moth deposits its eggs in standing grain and in the bin, singly and in clusters of from 20 to 30. The eggs, shown, much enlarged, in the illustration, are white when first laid, but soon turn red and hatch

in from four to seven or more days, when the minute larvæ or caterpillars burrow into the kernels and feed on the starchy interior. A single larva inhabits a grain of the smaller cereals, but maize affords sustenance for two or more individuals. A kernel of corn opened to show the larva at work is reproduced at fig. 2, *b*, and an ear of infested pop-corn is shown at fig. 3. In three weeks or more, according to season, the caterpillar attains maturity, when it spins within the kernel a thin, silken cocoon and transforms to a pupa or chrysalis, the moth emerging a few days later, the entire period from egg to adult embracing in summer time about five weeks and in colder weather considerably longer. After copulation, the moth deposits eggs for another brood, and thus several generations are produced in the course of a year. The older writers state that the species is double-brooded, but as it breeds continuously in harvested grain, there is now, as in the case of most indoor insects, an irregular development, influenced by temperature. In the latitude of the District of Columbia, in an outdoor exposure, such as is afforded by an old-fashioned corncrib, there are probably not more than four broods, the insect hibernating as larva in the grain, but in a heated atmosphere we have the possibility of five or six generations annually. In the warmer climate of the South, where the insect can breed uninterruptedly throughout the winter, it has been estimated that as many as eight generations may be produced.

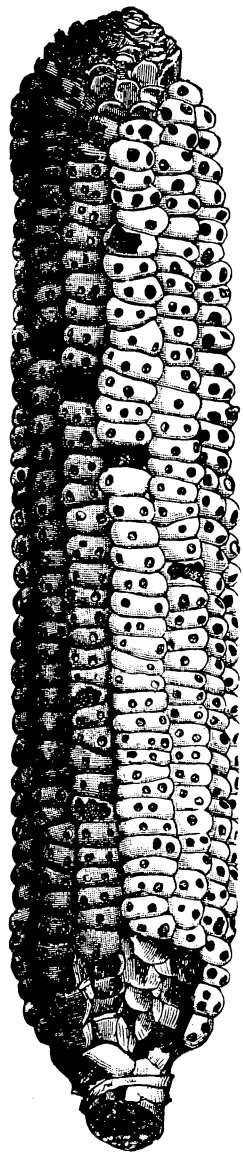

FIG. 3.—Ear of pop-corn showing work of Angoumois grain moth (from Riley in Ann. Rept. Dept. Agr., 1884).

THE WOLF MOTH (*Tinea granella* Linn.).

The wolf, or little grain moth, does considerable injury to stored cereals in Europe, but as it is not particularly destructive in America, requires only passing mention. This species is of about the size of the Angoumois moth, creamy white in color, thickly mottled with brown. Like the latter, it is known to oviposit in grain in the field. It infests cereals of all sorts, and a single caterpillar is capable of great damage, as it has a habit of passing from one grain to another, spinning them together with its webs as it goes, until twenty or thirty grains are spoiled. When full grown the caterpillars crawl all about the infested mass, leaving their webs everywhere, thus injuring even more than they consume.

## FLOUR AND MEAL MOTHS.

Four or five species of moths, in addition to the one just mentioned, are injurious to grain in store, but are more prevalent in mill products, and are troublesome as well by their depredations in a variety of articles.

### THE MEDITERRANEAN FLOUR MOTH (*Ephestia kuehniella* Zell.).

The most important of all mill insects is the Mediterranean flour moth. This scourge of the flour mill, as it is called, has attracted much attention of recent years and has been the subject of many articles and bulletins. Until the year 1877, when the moth was discovered in a flour mill in Germany, it was comparatively unknown. In later years it invaded Belgium and Holland, and in 1886 appeared in England. Three years later it made its appearance in destructive numbers in Canada. In 1892 it was reported injurious in mills in California, and in 1895 in New York and Pennsylvania.

That the Mediterranean flour moth has become so formidable in recent years is due to the higher and more equable temperature maintained in modern mills, a condition highly favorable to the development of the insect.

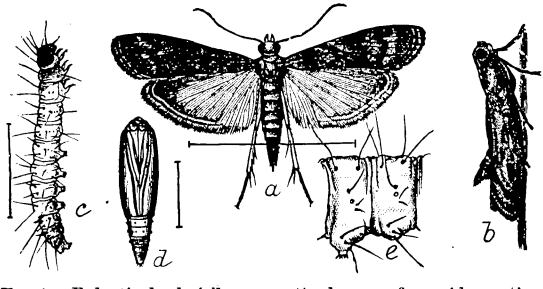


FIG. 4.—*Ephestia kuehniella*: *a*, moth; *b*, same from side, resting; *c*, larva; *d*, pupa—enlarged; *e*, abdominal joint of larva—more enlarged.

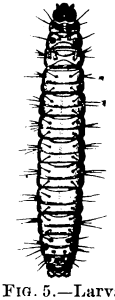

FIG. 5.—Larva, dorsal view (original).

Previous to the Canadian invasion this moth was generally believed to have reached Europe from America, but as a matter of fact the species had not been recognized here until 1889. Danysz has traced its occurrence in this country back as far as 1880. He mentions also an outbreak in Constantinople in 1872 and presents evidence that it was probably known in Europe as early as 1840. The species is recorded from specimens in collections from North Carolina, Alabama, New Mexico, Colorado, Mexico, and Chile. Of the last-mentioned localities it seems to be known as injurious only in Mexico. There is evidence to show that it probably occurs also in Australia.

The adult moth has a wing expanse of a little less than an inch; the fore-wings are pale leaden gray, with transverse black markings of the pattern shown in the accompanying illustration (fig. 4, *a*); the hind-wings are dirty whitish, semitransparent, and with a darker border. The caterpillar, illustrated at fig. 4 *c*, *e*, and at fig. 5, is whitish and hairy. The chrysalis, shown at fig. 4 *d*, is reddish brown.

The caterpillars form cylindrical silken tubes in which they feed, and it is in great part their habit of web spinning that renders them so injurious where they obtain a foothold. Upon attaining full growth the caterpillar leaves its original silken domicile and forms a new web, which becomes a cocoon, in which to undergo its transformations to pupa and to imago. It is while searching for a proper place for transformation that the insect is most troublesome. The infested flour becomes felted together and lumpy, the machinery becomes clogged, necessitating frequent and prolonged stoppage, and resulting in a short time in the loss of thousands of dollars, in large establishments.

Although the larva prefers flour or meal, it will attack grain when the former are not available, and it flourishes also on bran, prepared cereal foods, including buckwheat grits and crackers. In California it lives in the nests of a wild bumble-bee and in the hives of the honey bee.

In Europe it has been observed that the insect is able to complete its life cycle in two months, but from experiments recently conducted at Washington it has been demonstrated that under the most favorable conditions—i. e., in the warmest weather—the life cycle may be passed in thirty-eight days. In its outdoor life there are probably not more than two or three broods in the year, but in well-heated mills or other buildings six or more generations may be produced.

This insect is rapidly becoming distributed throughout the civilized world, but as yet its range is limited. From the reports of its alarming destructiveness in Great Britain and Canada, it would readily be inferred that this moth is peculiarly qualified for an indoor existence in much colder climates than most other grain insects.

When a mill is found to be infested, the entire building should be fumigated, and in case a whole district becomes overrun the greatest care must be observed not to spread the infestation. Uninfested mills should be tightly closed at night, and every bushel of grain, every bag or sack brought into the mill, subjected to a quarantine process, by being disinfected either by heat or bisulphide of carbon.

### THE INDIAN-MEAL MOTH (*Plodia interpunctella* Hbn.).

An insect known as the Indian-meal moth may often be seen flying about in mills and stores, where it feeds on edibles of almost every kind—meal, flour, bran, grain of all sorts, dried fruits, seeds and nuts, condiments, roots, and herbs.

The adult moth is shown in the accompanying illustration (fig. 6, *a*). It measures across the expanded wings between a half and three-fourths of an inch. The inner third of the fore-wings is dirty whitish gray, and the outer two-thirds are reddish brown, with a dull coppery luster. The caterpillar is shown at *c*, *e*, *d*, and *f* and the chrysalis at *b*.

The caterpillars spin large quantities of silken threads with which they fasten together seeds, grain, or particles of whatever material they happen to infest, and it has recently been observed that they have a

special fondness for the embryo of wheat and pass from grain to grain, devouring only the germ, and attaching them together as they go. As they also deposit large quantities of excrement which becomes attached to the silk it will be seen that they injure both for seed and for food many times the amount of grain actually consumed.

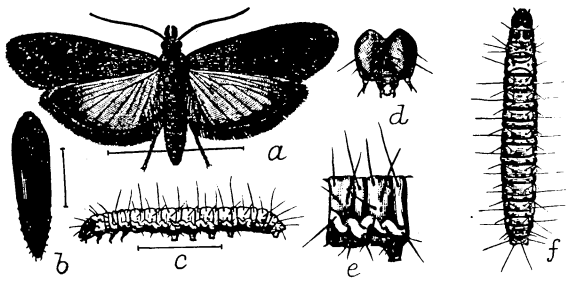


FIG. 6.—*Plodia interpunctella: a*, moth; *b*, chrysalis; *c*, caterpillar; *f* same dorsal view—somewhat enlarged; *d*, head, and *e*, first abdominal segment of caterpillar—more enlarged (author's illustration).

Experiment shows that the insect is capable of passing through all its several stages, from egg to adult, in five weeks, which furnishes a possibility of six or more generations in a well-heated atmosphere, although in a moderately cool granary or other storehouse four or five broods is probably the normal number per annum.

THE MEAL SNOUT-MOTH (*Pyralis farinalis* Linn.).

This meal moth often occurs where edible products are housed. It is slightly larger than the species previously mentioned, having a wing expanse of nearly an inch. The ground color is light brown, with reddish reflections; the thorax and the dark patches at its sides and near the tips of the fore-wings are darker brown. The wavy, transverse lines of the wings are whitish, and form the pattern indicated in the illustration (fig. 7, *a*). The caterpillar and chrysalis are figured, twice natural size, at *b* and *c*, respectively. In its habits it somewhat resembles the preceding species. The caterpillar constructs peculiar long tubes of silk and particles of the meal or other food upon which it lives. It infests cereals of all kinds and conditions, in the kernel or in the form of flour, meal, bran, or straw. It also attacks other seeds and dried plants, injures hay after the manner of the related clover-hay worm, and has been reported injurious to potatoes.

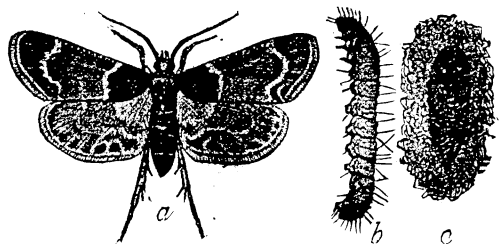


FIG. 7.—*Pyralis farinalis: a*, adult moth; *b*, larva; *c*, pupa in cocoon—twice natural size (author's illustration).

The life history of the meal snout-moth has not until recently been properly understood, the efforts to rear and observe it having always proved unsatisfactory. Certain European writers have expressed the belief that the species is biennial in development, but experiments

now being conducted go to prove at least four generations a year. The species has been carried through all its stages this spring in about eight weeks. It appears to require a certain amount of moisture, such as is present in "heated" grain or hay, for its full development.

No danger need be apprehended from injuries by this insect if material upon which it is likely to feed be kept in a clean, dry place. Almost without exception the cases of damage attributable to it have occurred in cellars, upon floors, in outhouses, or in places where refuse vegetable matter has accumulated.

### THE FLOUR BEETLES.

Several little flattened beetles, of a shining brown color and similar appearance generally, so frequently occur in bags and barrels of flour as to have earned the popular title of "flour weevils." They live upon cereal and other seeds and various other stored products, but generally prefer flour and meal and patented articles of diet containing farinaceous matter.

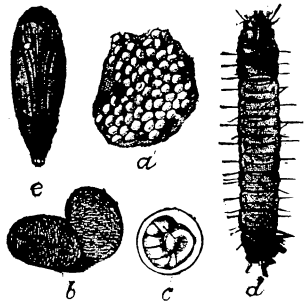


FIG. 8.—*Pyralis farinalis: a*, egg mass; *b*, eggs—more enlarged; *c*, egg showing embryo within; *d*, larva, dorsal view; *e*, pupa—all enlarged (author's illustration).

Their eggs are often deposited in the flour in mills, and these and the larvæ they produce being minute and pale in color readily escape notice; but after the flour has been barreled or placed in bags and left unopened for any length of time the adult beetles make their appearance, and in due course the flour is ruined, for when the insects have time to propagate they soon convert the flour into a gray, useless mass. A part of the annoyance to purchaser, dealer, and manufacturer is due to the fact that the insects are highly offensive, a few specimens being sufficient to impart a disagreeable and persistent odor to the infested substance.

#### THE CONFUSED FLOUR BEETLE (*Tribolium confusum* Duv.).

The most important of the flour beetles is the one above mentioned. It is about the same size as the true grain weevils, is of nearly universal occurrence in grain of all kinds following the attacks of the latter species with which it is very often associated. Its principal damage, however, appears to be to flour and other patented articles of diet containing starchy matter; in fact, it is without doubt the insect most injurious to prepared cereal foods, if we except the Mediterranean flour moth, which fortunately is as yet confined to a limited territory.

Although known for many years in Europe as an enemy to stored cereals, seeds, and even as a pest in museums, it was not until the fall of 1893 that it was recognized in this country as a species distinct from others of its kind. In less than two years from the time of its first recognition here, this insect had been reported as injurious in nearly every

State and Territory. The divisional experience of a single year, 1894, shows that more complaints are made of injuries by this than of any other granivorous insect. As a mill pest it was the most troublesome species of 1895, and annually costs the millers of the United States thousands of dollars by its presence in manufactured products.

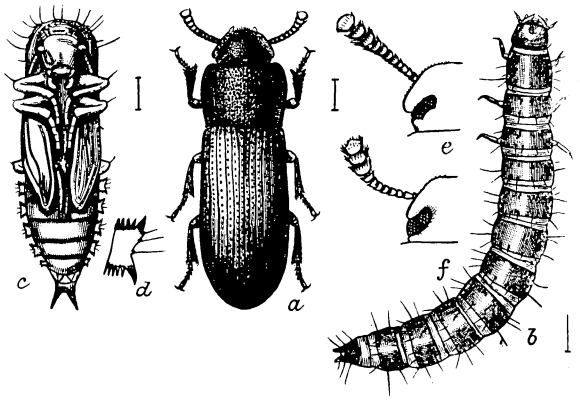


FIG. 9.—*Tribolium confusum*: *a*, beetle; *b*, larva; *c*, pupa—all enlarged; *d*, lateral lobe of abdomen of pupa; *e*, head of beetle, showing antenna; *f*, same of *T. ferrugineum*—all greatly enlarged (author's illustration).

The mature beetle is scarcely a sixth of an inch long, elongate, and flattened, brown in color, and of the form indicated in the illustration (fig. 9, *a*). The head, with antenna, is shown, much enlarged, at *e*, and the general characters of the larva are illustrated at *b*, the pupa at *c* and *d*.

Among the many substances attacked by this insect may be mentioned, besides grain and its manufactured products, snuff, orris root, baking powder, rice chaff, red pepper, ginger, slippery elm, peas, beans, nuts, and seeds of various kinds, in all of which it has been found by the writer. It sometimes also invades cabinets of dried insects.

From experiment it has been learned that this species, in an exceptionally high temperature, is capable of undergoing its entire round of transformations in thirty-six days, but in spring and autumn weather it requires a much longer time. In well-heated buildings at this rate there are at least four broods a year.

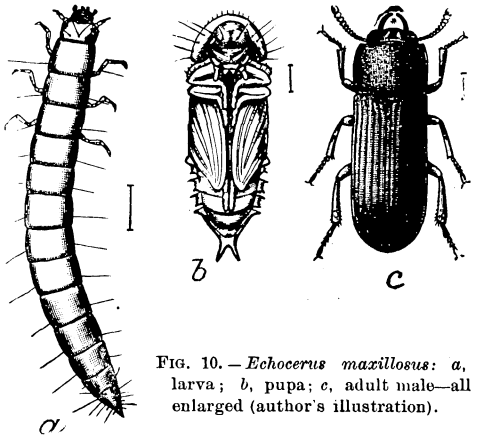


FIG. 10.—*Echocerus maxillosus*: *a*, larva; *b*, pupa; *c*, adult male—all enlarged (author's illustration).

OTHER FLOUR BEETLES.—Other species of flour beetles are injurious in the same manner, but as yet are much less widely distributed in this country. Prominent among these in the Southern States are the following:

THE RUST-RED FLOUR BEETLE (*Tribolium ferrugineum* Fab.).

This resembles the preceding species in color, form, and size, but may be distinguished by the form of the head, which is not expanded

beyond the eyes at the sides and by the antennæ, which terminate in a distinct three-jointed club (see fig. 9, *f*). In its habits and life history it also closely resembles the preceding, but it is apparently somewhat restricted to the Southern States, although occasionally found in the North. It is often reported in flour, meal, and grain, and is sometimes shipped north in consignments of rice.

THE SLENDER-HORNED FLOUR BEETLE (*Echocerus maxillosus* Fab.).

The above-named insect should be mentioned here. It also feeds on flour and meal and is of frequent occurrence in the South and has been found as far north as the District of Columbia and southern Ohio in Indian corn, which appears to be its preferred food. The beetle resembles the two preceding species, but is lighter in color and a little smaller, measuring a trifle over an eighth of an inch in length. On the head, between the eyes, are two pointed tubercles, and the mandibles in the male are armed with a pair of slender, incurved horns. The insect in its several stages is illustrated at fig. 10.

FIG. 11.—*Echocerus cornutus*: male—enlarged (author's illustration).

THE BROAD-HORNED FLOUR BEETLE (*Echocerus cornutus* Fab.).

A flour beetle that sometimes finds its way into stores is the one above mentioned. It also closely resembles preceding species, but may be distinguished from them by the broad, conspicuous mandibular horns in the male (see fig. 11). It has been found in ground cereals of various sorts, including flour, meal, "germea," rolled barley, bread, army biscuit, maize, wheat, and rice. In southern California it occurs even under bark, showing complete acclimatization. Its distribution in the United States is at present limited, but it is frequently met with in seaport towns, especially on the Pacific Coast, and is on the increase elsewhere. In some parts of Europe it is a veritable pest in bakeries by getting into the flour and into the masses of fermenting dough that accumulate upon the molds used in baking bread.

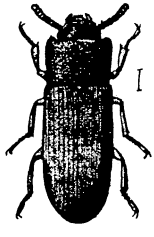

FIG. 12.—*Palorus ratzeburgi*—much enlarged (original).

THE SMALL-EYED FLOUR BEETLE (*Palorus ratzeburgi* Wissm.).

The smallest of the flour beetles known to injure cereals in this country is the one figured herewith. It looks not unlike preceding species, but, by comparison of specimens with a good lens, the differences are apparent. Although seldom recognized it is already known to be more widely distributed in the United States than at least two of the preceding forms. The first report of its occurrence in this country was in 1882, when it was the cause of much annoyance in a mill near Detroit, Mich. In the District of Columbia it ranks second among flour beetles in abundance and injuriousness in feed stores, bakeries, and other places where cereal products are kept

in store. In its habits it does not differ appreciably from other flour beetles, being much more injurious to ground products than to the seed of cereals.

THE MEAL-WORMS.

Two species of beetles and their larvæ, the latter known under the familiar name of "meal-worms," attract attention by reason of their large size and somewhat serpent-like appearance when present in open flour barrels, feed boxes, and bags of bran or meal. They are among the many species that develop in refuse grain dust and mill products that are carelessly permitted to accumulate in the dark corners and out-of-the-way places in flouring mills, bakeries, feed stores, pigeon lofts, and stables. The two species are about equally common and do not differ materially in their habits, and, although abundant enough wherever grain is stored, do little or no damage to seed stock, being found mostly in corn meal and other ground products. They are also sometimes injurious to ship biscuit. As with some of the other storehouse insects, the Tenebrios are not an unmixed evil, for they have a commercial value to the bird fancier, being used as food for nightingales, mocking birds, and other feathered pets.

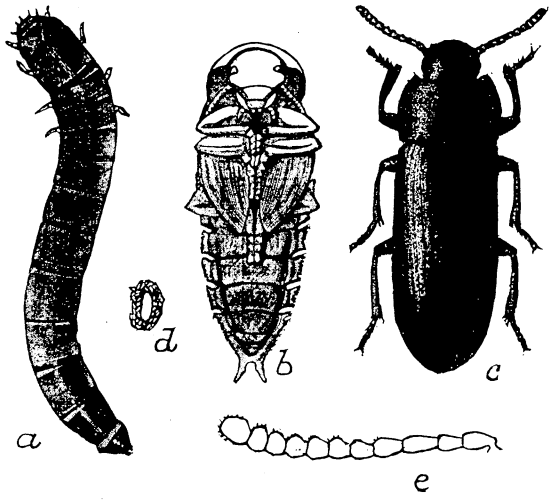


FIG. 13.—*Tenebrio molitor: a*, larva; *b*, pupa; *c*, female beetle; *d*, egg, with surrounding case; *e* antenna—*a*, *b*, *c*, *d*, about twice natural size; *e*, more enlarged (original).

THE YELLOW MEAL-WORM (*Tenebrio molitor* Linn.).

The above-mentioned species is the meal-worm most often referred to in scientific literature, and as it is in the larval stage that it is best known, the name yellow meal-worm has been suggested to distinguish it from the other species, which is much darker in color. The larva (see fig. 13, *a*) is cylindrical, long, and slender, attaining a length of upward of an inch, and being about eight times as long as broad. It is waxen in appearance, resembling a wireworm. In color it is yellow, shading to darker ochreous toward each end and near the articulation of each joint. The anal extremity terminates in two minute spines. The pupa (*b*) is white, and the adult insect, as will be seen by reference to the illustration, resembles on a large scale one of the flour

beetles. It is considerably over half an inch long, somewhat flattened, shining, and nearly black. An enlarged antenna is shown at *e*.

The eggs, one of which is shown at *d*, with its covering of meal, are white, bean-shaped, and about a twentieth of an inch long, and are deposited by the parent beetle in the meal or other substance which is to serve as the food of the future larva.

The beetles begin to appear in the latitude of Washington in April and May, occurring most abundantly in the latter month and in June. In about two weeks from the time the eggs are laid the infant meal-worm, which is at first clear white in color and with prominent antennæ and legs, makes its appearance, and as it feeds voraciously its growth is rapid. In three months it attains approximate growth, and from then till the following spring undergoes little change. It then becomes a pupa, and in this state remains about a fortnight. It will therefore be seen that this species is annual in development, a single brood only appearing each year. The beetles are nocturnal, and, being moderately strong flyers, are often attracted to lights. They have the pungent odor characteristic of the flour beetles and related species.

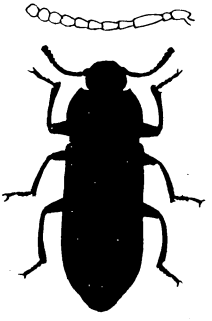

FIG. 14—*Tenebrio obscurus*: male—somewhat enlarged (original).

THE DARK MEAL-WORM (*Tenebrio obscurus* Linn.).

The darker of the two meal-worm larvæ has been called by writers the American meal-worm, an obvious misnomer, as this species, like the preceding, is believed by scientists to have come originally from temperate Europe or Siberia and is, like other species most commonly found in the storehouse, an introduced cosmopolite.

The mature insect, illustrated at fig. 14, is very similar to the parent of the yellow meal-worm, being of nearly the same dimensions but distinguishable by its color, which is dull piceous black. There are other points of difference, notably in the antennæ, the third joint in the present species being perceptibly longer than in *molitor*. The larva also resembles that of the preceding, differing chiefly in its much darker brownish markings. The pupa, however, is of the same whitish color.

The beetles, in the writer's experience, begin to appear considerably earlier than do those of the yellow meal-worm. Hence, at Washington they may be found as early as the latter part of February, remaining till the first of July, occurring most abundantly in April and May.

THE GRAIN BEETLES.

Several species of clavicorn beetles of the family Cucujidæ occur in granaries, mills, and warehouses in the same situations as species previously treated. One of these is practically confined to the storehouse, usually following in the wake of other grain insects. The other two are

more often found in the open, but are capable of damage to stored foods if once they take up their habitation where these materials are kept.

THE SAW-TOOTHED GRAIN BEETLE (*Silvanus surinamensis* Linn.).

This little beetle is widely distributed over the entire globe, and of common occurrence in granaries and almost everywhere where edibles are stored. It is nearly omnivorous, infesting grain, flour, meal, dried fruits and seeds of all sorts, breadstuffs, and other comestibles, and though usually following the attacks of other insects is often reported as doing considerable damage.

The adult is very small, only about one-tenth of an inch long, slender, much flattened, and of a dark, chocolate-brown color. The antennæ are clavate, or club-shaped, and the thorax has two shallow longitudinal grooves on the upper surface and bears six saw-like teeth on each side, as shown at fig. 15, *a*.

The larva is nearly white, and, as will be noticed by reference to the illustration (*c*), has six legs and an abdominal proleg. It is exceedingly active, and does not pass its life wholly within a single seed, but runs about nibbling here and there. After attaining its growth the larva attaches itself to some convenient surface and constructs a covering by joining together small grains or fragments of infested material by means of an adhesive substance which it secretes, and within this case the pupa (*b*) and afterwards the adult states are assumed.

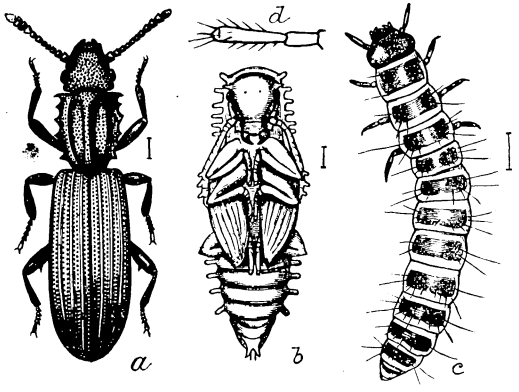


FIG. 15.—*Silvanus surinamensis*: *a*, adult beetle; *b* pupa; *c*, larva—all enlarged; *d*, antenna of larva—still more enlarged (author's illustration).

It is estimated that there are usually four, and that there may be as many as six generations of this insect annually in the latitude of the District of Columbia. During the warmest summer months the life cycle requires but twenty-four days; in early spring, from six to ten weeks. At Washington the species winters over, in the adult state, even in a well-warmed indoor atmosphere.

The mature beetles will feed upon sugar, and have been reported in starch, tobacco, and dried meats, but it is doubtful if the insect will breed in such substances. The beetles or their larvæ have a bad habit of perforating the paper bags in which flour and other comestibles are kept. When present in boxes of fruit there may be no visible evidence of their presence until the bottom is reached, but here they will be found in great numbers and when disturbed scamper off in great haste. This insect is almost invariably present wherever the Indian-meal

moth is found and the list of the food products that have been mentioned as subject to this moth's attack will answer about equally well for the beetle.

THE RED OR SQUARE-NECKED GRAIN BEETLE (*Cathartus gemellatus* Duv.).

An injurious enemy of Southern grain is the red or square-necked grain beetle which is illustrated at fig. 16. It is of about the same length as the preceding species, to which it is nearly related and somewhat resembles, but the head and thorax are nearly as broad as the abdomen; the thorax is nearly square, not serrated on the sides, and the color is shining reddish-brown. In its earlier stages it also resembles the saw-toothed species.

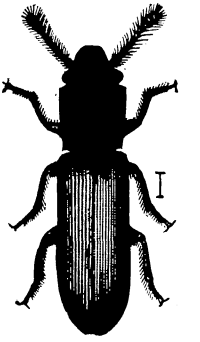

FIG. 16.—*Cathartus gemellatus* (original).

It breeds in corn in the field as well as in cotton bolls and overripe or dried fruits, and continues breeding in harvested grain. It has been said that corn injured by this species has little chance of germinating, as the germ is nearly always first destroyed, and that this fact may, in some degree, account for the numerous failures of seed corn to grow, of which Southern planters so often complain. It is essentially an outdoor species, but when conditions favor its increase may become a serious pest in the granary, as it is capable of breeding from egg to adult in the short period of three weeks.

THE FOREIGN GRAIN BEETLE (*Cathartus advena* Waltl.).

The third grain beetle that will be considered is congeneric with the last. In life it is of a similar reddish color, but may be distinguished from the square-necked species by its smaller size. It is more robust, its thorax and elytra being proportionately wider (see fig. 17). Though an insect of wider distribution and diversity of food habits it has received scant attention at the hands of naturalists and its life economy has not been very fully studied.

FIG. 17.—*Cathartus advena*—much enlarged (original).

In the correspondence of the Division it has been reported injurious to stored wheat, to corn in stack, and to dried parsley, and has been found by the writer living in middlings, rice, dates, figs, table beans, cacao beans, and edible tubers. It has been also reported in abundance in flour, and during the year was taken in a feed store in this city.

In breeding experiments recently conducted by the writer it failed to develop in fresh grain or meal, but bred freely in corn meal which was moistened to produce mold. The beetles, particularly, fed freely on the molds, of which there were three or four species, and

it would appear that this is the normal habit of the insect. Hence, although this species may do a certain amount of injury to grain, little fear need be felt of any serious damage, provided the grain be stored in a clean, dry, well ventilated place.

## THE CADELLE.

(*Tenebroides mauritanicus* Linn.).

The cadelle stands in a class by itself. It is almost as widely distributed as any of the preceding species, and did it not differ from all of them (except the meal-worms), in being annual in development as well as in being partially predaceous, might rival them in point of injuriousness.

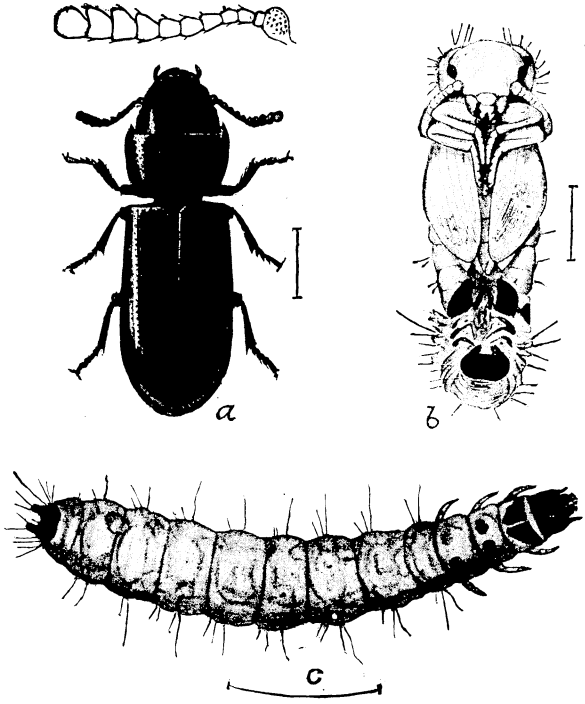


FIG. 18.—*Tenebroides mauritanicus: a*, adult beetle with greatly enlarged antenna above; *b*, pupa; *c*, larva—all enlarged (author's illustration).

The adult beetle, shown at fig. 18, *a*, is an elongate, oblong, depressed beetle, nearly black in color, and about one-third of an inch in length. The larva (*c*) is fleshy and slender, and measures when full grown nearly three-fourths of an inch. Its color is dull whitish, with a dark-brown head. The three thoracic segments are also marked with dark brown, and the tail terminates in two dark horny points. The pupa (shown at *b*) is also white.

The statements of some of the earlier writers that this species is granivorous has been discredited by later authors. It has been experimentally proven by the writer, however, that the insect lives both in

the larval and adult conditions upon grain; and furthermore, that were the insect more prolific it would become a source of much damage to seed stock from its habit of devouring the embryo, or germ, going from kernel to kernel and destroying for germinating purposes many more seeds than it consumes. Both larvæ and beetles serve a good purpose by attacking and destroying whatever other grain insects they happen to encounter.

### PARASITIC AND OTHER NATURAL ENEMIES.

It might be supposed that insects which live a retired indoor existence would be comparatively free from parasitic and other enemies, but such is not the case.

It has been estimated of the granary weevil that one pair in the course of a year would produce 6,000 descendants. The moths are still more prolific, and as there are six or more broods of some species annually it will be seen that if all the eggs of one individual and her offspring develop there would be produced in one year a whole myriad of the insects, sufficient to destroy many tons of grain.

Fortunately, there are several natural checks to the undue increase of these insects. One of them is a diminutive mite which preys upon various species. Spiders that inhabit mills and granaries entrap the moths, and in the field they are preyed upon by nocturnal insects as well as by birds and bats.

The grain weevils and the Angoumois moth are often parasitized, two or three species of chalcis flies having been recognized as the enemies of each. The flour and meal moths each have several parasites, and most other granary insects are known to have either parasitic or predaceous enemies.

The good work that is sometimes done by parasites in limiting the multiplication of their grain-feeding hosts is exemplified in a case cited of the Mediterranean flour moth having been destroyed by a parasite when other means had failed to dislodge it in the warehouses which it had invaded.

### METHODS OF CONTROL.

The measures to be employed in the control of insects affecting stored products are both preventive and insecticidal. As an insecticide nothing answers the purpose so well as the bisulphide of carbon, which is a nearly perfect remedy against all insects that infest the storehouse. The remedies that will be discussed in the present circular, while intended primarily for use against insects in stored grain, have an almost equal value against all forms of animal life that occur in products that are dried and kept in storage.

#### PREVENTIVE MEASURES.

A limited number of insects, like the Angoumois grain moth in the extreme South, enter the grain in the field, and certain precautions are therefore necessary to prevent their access to the granary. This is

accomplished, first, by harvesting as soon as the grain is ripe; second, by threshing as soon afterwards as possible.

In the process of threshing or cleaning much infested grain is blown out with the chaff and dust, and the moths and many adult weevils are killed by the agitation which the grain receives; but the immature forms of these insects, concealed in the kernels as eggs, larvæ, and pupæ, are apt to survive this treatment, and further measures are necessary for their destruction.

For this purpose a quarantine bin is desirable, to be as nearly air-tight as possible, in which the newly threshed as well as the infested or suspected grain can be fumigated with bisulphide of carbon, according to the directions given on page 22.

Fresh grain should not be exposed to insect attack by being placed in bins with "weeviled" grain, or even housed under the same roof with such grain. If before storing in buildings that have been infested, the old grain be removed, the bins thoroughly cleaned, floors, walls, and ceilings brushed and scrubbed, the chances of infestation will be reduced to a minimum. If the storehouse has been badly infested, a fumigation with bisulphide is necessary.

The recent appearance of that most pernicious of mill pests, the Mediterranean flour moth, on the Pacific Coast and in certain locations in the East, has made indispensable the use of the bisulphide of carbon and the quarantine bin, and has brought to the fore a number of mechanical devices for its control. One of these is called a "steam sweeper," and certain mills in neighborhoods that are infested with this moth are already equipped with it. A steam pipe is run under the ceiling of each floor, and at intervals of about 25 feet a steam cock is placed, to which can be attached a hose for steaming the spouts and other portions of the infested machinery and all parts of the mill. The flour moth, as is well known, causes much trouble when in the larva or "worm" state by crawling into the spouts and elevator legs, where they spin their webs and clog the apertures. The liability of danger from this source may be obviated by the substitution of metal for the wooden apparatus generally in use, and already a metal spout has been patented and a metal elevator leg been devised for the express purpose of preventing this and other injurious insects from establishing themselves in these portions of the mill. Another device, called the "elevator brush," has been called into use to prevent the larvæ from choking up wooden spouts and elevator legs.

In times when the Angoumois grain moth was so injurious in France a number of machines were devised for the treatment of infested grain. Into these the grain is poured and revolved while exposed to heat or subjected to a violent agitation which kills the contained insects.

Cleanliness will accomplish much toward the prevention of injury from warehouse pests, the cause of a great proportion of injuries in granaries, mills, elevators, and other structures where grain and feed are stored being directly traceable to a disregard of neatness. Dust,

dirt, rubbish, and refuse material containing sweepings of grain, flour, and meal are too frequently permitted to accumulate and serve as breeding places for a multitude of injurious insects.

The floors of the storehouse should be frequently swept, and all material that has no commercial value burned.

A certain amount of attention has always been given to the construction of the storehouse with a view to the exclusion of insects, and, with the advent of the flour moth, our modern mills are being fitted with reference to its peculiar habits.

The ideal farmer's granary, from the standpoint of insect ravages, should be built at some distance from other buildings and the rooms constructed so as to be as near vermin proof as possible. The doors should fit tightly, and the windows covered with frames of wire gauze to prevent the passage of insects. The floor, walls, and ceilings should be smooth, so as not to afford any lurking places for the insects, and it would be well to have them oiled, painted, or whitewashed for further security. A coating of coal tar has been strongly recommended for the latter purpose. Such measures are not an absolute necessity in cold and temperate climates, but in the more heated atmosphere of our Southern States whatever possible should be done to lessen the chances of damage.

One of the latest things in the way of grain storage in connection with mills is the adoption of steel tanks for this purpose, for an account of which the reader is referred to the American Miller of May, 1896. It is claimed that the tanks are air-tight and fireproof and that in them "grain can be kept intact from any and all the destroying elements for an indefinite time."

The value of a cool place as a repository of grain has been known of old, and a building in which any artificial heat is employed is undesirable for grain storage. The "heating" and fermentation of grain, as is well known, is a productive source of "weevil," and this should be prevented by avoiding moisture and by ventilation.

The storage of grain in large bulk is to be commended, as the surface layers only are exposed to infestation. This practice is particularly valuable against the moths, which do not penetrate far beneath the surface. Frequent agitation of the grain is also destructive to the moths, as they are unable to extricate themselves from a large mass, and perish in the attempt. The rice and granary weevils, however, penetrate more deeply, and, although bulking is of value against them, it is not advisable to stir the grain, as it merely distributes them more thoroughly through the mass.

Many remedies have been proposed for use against stored grain insects, mostly of impractical or doubtful utility, and a long list of such substances, which are chiefly of a supposed repellant nature, could be given. The few of these which might be of value must be used in large quantity and in tight receptacles to be effective.

The most effective deterrent is naphthaline, which when used in tight

receptacles is an almost perfect preservative of seed stock and other products subject to insect attack. Its use is not, however, desirable with material that is to be used as food on account of its powerful and permanent odor. Salt, air-slaked lime, and powdered sulphur also serve the same purpose, but their use is also objectionable for different reasons.

INSECTICIDES AND OTHER DESTRUCTIVE AGENCIES.

Prior to the adoption of the bisulphide of carbon as a fumigant, heat was relied upon in the destruction of these insects. A temperature of from 125° to 140° F., continued for a few hours, is fatal to grain insects, and wheat can be subjected to a temperature of 150° for a short time without destroying its germinating power. Kiln-drying, at a still lower degree of heat, has been found effective.

A low temperature is equally destructive, and in colder climates these insects may be successfully dealt with by stirring or turning the infested grain, or by filling the buildings with steam and then throwing open the windows at night and exposing the insects to frost.

Steam, as has been said, is in successful use against the flour moth, and is employed in the same manner as bisulphide of carbon for the disinfection of bags and machinery in the quarantine box.

Sulphur, properly applied, may be used with benefit when for any reason the use of bisulphide is not advisable, and sulphur combined with steam is particularly destructive to insect life. Its use, however, is attended with certain disadvantages, necessitating the removal of all grain, as the former is apt to be injured for flour-making and the latter for bread-making purposes.

Benzine and naphtha or gasoline are of some value as fumigants for some materials, but do not produce entirely satisfactory results with grain, their vapors being insufficient for the destruction of the adolescent stages of species which breed wholly within the kernel, while each of these reagents possesses an offensive and more or less persistent odor. They are open, moreover, to the same objections as bisulphide of carbon, the vapor being about equally inflammable and more explosive.

THE BISULPHIDE OF CARBON TREATMENT.

The simplest, most effective, and inexpensive remedy for all insects that affect stored cereal and other products is the bisulphide of carbon, a colorless liquid with a strong, disagreeable odor, which, however, soon passes away. It vaporizes abundantly at ordinary temperatures, is highly inflammable, and is a powerful poison.

It may be applied directly to infested grain or seed without injury to its edible or germinative principles by spraying or pouring, but the most effective manner of its application in moderately tight bins or other receptacles consists in evaporating the liquid in shallow dishes or pans, or on bits of cloth or cotton waste distributed about on the surface of the infested material. The liquid rapidly volatilizes, and

being heavier than air descends and permeates the mass of grain, killing all insects and other vermin present.

The bisulphide is usually evaporated in vessels containing one-fourth or one-half of a pound each, and is applied in tight bins at the rate of a pound to a pound and a half to the ton of grain, and in more open bins a larger quantity is used. For smaller masses of grain or other material an ounce is evaporated to every 100 pounds of the infested matter. Bins may be rendered nearly air-tight by covering with cloths, blankets, or canvas.

Infested grain is generally subjected to the bisulphide treatment for twenty-four hours, but may be exposed much longer without harming it for milling purposes. If not exposed for more than thirty-six hours its germinating power will not be impaired. In open cribs and badly infested buildings it may sometimes be necessary to use a double quantity of the reagent and repeat treatment at intervals of about six weeks during the warmest weather.

Mr. H. E. Weed, entomologist of the Mississippi Experiment Station, claims that 1 pound to 100 bushels of grain is amply sufficient to destroy all insects, even in open cribs.

Mills and other buildings, when found to be infested throughout, may be thoroughly fumigated and rid of insects by a liberal use of the same chemical. A good time for this work is during daylight on a Saturday afternoon or early Sunday morning, closing the doors and windows as tightly as possible and observing the precaution of stationing a watchman without to prevent anyone from entering. It is best to begin in the lowest story and work upward, to escape the settling gas. The building should then be thoroughly aired and the grain stirred early Monday morning.

For the fumigation of a building or a reasonably close room it is customary to evaporate a pound of the bisulphide for every thousand feet of cubic space. In comparatively empty rooms, and in such as do not admit of being tightly closed, two or three times the above quantity of the chemical is sometimes necessary.

Certain precautions should always be observed. The vapor of bisulphide is deadly to all forms of animal life if inhaled in sufficient quantity, but there is no danger in inhaling a small amount. The vapor is inflammable, but with proper care that no fire of any kind, as, for example, a lighted cigar, be brought into the vicinity until the fumes have entirely passed away, no trouble will be experienced.

Bisulphide of carbon retails at from 20 to 30 cents a pound, but at wholesale, in 50-pound cans, may be obtained for 10 cents a pound. A grade known as "fuma bisulfide," for sale at the latter price, is said to be more effective than the ordinary commercial article.

At the rate used the cost of treatment is from 10 cents and upward for each ton of grain.

SUMMARY OF PRINCIPAL REMEDIES AND PREVENTIVES.

The bisulphide of carbon by reason of its intensive action is the best known remedy against all insects that affect stored products, and for this purpose is becoming indispensable, but in addition to its use various other measures, principally preventive, may be observed with profit for the preservation of grain against insect attack. The principal coordinate or additional measures may be summarized as follows:

(1) Prompt threshing to prevent the Angoumois grain moth, rice weevil, and some other species in the extreme South, from obtaining access to the granary.

(2) Inspection, quarantining, and disinfection of infested or suspected grain, bags, and machinery before permanent storage.

(3) Scrupulous cleanliness, including the prompt destruction of refuse material, which will accomplish much in lessening the chances of injury.

(4) Constructing or refitting the warehouse or mill, especially in warm latitudes, with a view to the exclusion of insects.

(5) Substitution of metal, for wooden, spouts, etc., and the use of other improved machinery in mills infested with the flour moth.

(6) Storage in large bulk, particularly valuable against grain moths.

(7) Storage in a cool, dry repository, well ventilated to prevent "heating."

(8) The use of naphthaline as a preservative of small samples in tight receptacles.

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**INVESTIGATION OF INSECTS AFFECTING STORED PRODUCTS.**

The Division of Entomology is engaged in a special investigation of the insects that infest stored products, including grain, flour, meal, patented foods, peas, beans, dried fruits, nuts, seeds of different kinds, herbs and dried plants, drugs, leather, dried meats, woolen and other fabrics, specimens of natural history, etc.

Information is desired of anything new or of unusual interest, and correspondence is invited. Communications should be accompanied where possible by specimens of the insects concerned, with full statements regarding the extent of the injuries. Such facts as may be gathered through correspondence will be reserved for publication if of sufficient value, but the names of correspondents and of localities infested will be withheld unless permission is given for their use in this connection.

The person to whom this bulletin is sent is respectfully requested to bring the matter to the attention of some farmer, miller, or grocer or other merchant of his neighborhood who may suffer from the presence of these insects in his granary, mill, or storehouse and who may desire advice in regard to the best methods of controlling them.

The experience of persons who have had an opportunity to test on a large scale the bisulphide of carbon and other remedies for stored-product insects is also solicited.

Address: Division of Entomology, U. S. Department of Agriculture, Washington, D. C.

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